Chapter 2. Science Policy: The Rationale for Public Support[1]

By Elizabeth L. Malone

In the last half of the twentieth century, science has enjoyed a long boom -- unprecedented progress, widespread and increasing support from government and industry, and generally favorable attitudes from the public at large. Policymakers and the public have credited basic research with longer and healthier human lives; huge increases in agricultural production; and immense improvements in transportation, energy production, and communications.

During this time, a rationale for public support of basic research became firmly established and elaborated. First, basic research is, according to the rationale, the foundation for technological development, which provides military and economic advantages to countries that are technologically advanced. Second, government support of science is necessary because the private sector, being unable to realize individual competitive advantages from basic research, has insufficient motivation to undertake it. Consequently, the government's investment in basic research is a "public good," providing the basis for national competitiveness in politics and in markets, expansion of knowledge, and continuing improvement in the quality of life.

At the same time, a different function of scientific research has emerged – science as a base of knowledge upon which to build policy. Policy's need for science has generated whole sub-specialties of science, e g., toxic waste disposal. Policies on health, education, energy, the environment, etc., now require scientific findings and "risk-based decision-making." Sometimes characterized as "speaking truth to power," this function of scientific research has brought it more explicitly into the political arena. When research results can be attached to a particular political philosophy, the area of research that produced the results, and the organizations that sponsor it, can be labeled as partisan rather than objective.

Almost all disciplines have shared in science's long boom -- but in recent years the federal government has been reducing its share of investment in some areas and overall, while increasing support in other areas. Questions about the "return on investment" in basic research have been raised, the role of industry in basic research has resurfaced, the role of government in facilitating the commercialization of technology emerging from basic research has received greater attention, and governments have established methods to evaluate the performance of government-funded research. In addition, globalization, the end of the cold war, and burgeoning international collaborations are calling into question the traditional justifications of national competitiveness and raising issues of capacity building.

In this context, managers of publicly funded science need to understand the historical bases for government support and the root issues underlying the current debates. Science policy and trends in public funding for science have been shaped by debate about the function of science in society and the appropriate division of responsibility between the public and private sectors for directing and supporting scientific research and development. Beyond the immediate arguments about what gets funded and at what level are questions about the nature of science, the justification for government funding, and evaluating such a long-term and inherently uncertain activity.

---

[1] Related chapters include: Strategy; Change Management; Performance Assessment; Competencies; Organizational Alliances; Leadership; Innovation; Creativity; Scientific Ethics; Communicating Science.

Brief History and Current Situation

During the Scientific Revolution in the sixteenth and seventeenth centuries, science was conceptualized as the highest intellectual calling of a scholar, with scientist-scholars taking on questions of philosophical and religious importance, trying to understand the fundamental laws of nature and society with the aim of improving people and their world. Science was defended for its intrinsic value and reflection of human intellect and spirit of inquiry, one justification that is still used. Scientists were largely self-funded, independent of government support.

Governments quickly came to see advantages in scientific advances and allied themselves with investigations that seemed influential and/or likely to result in tangible advantages of improvements in war making, political control, or market domination. “From the eighteenth century, most scientists believed not only that knowledge would increase through the support of political power, but that political power itself is tied to contributions from science” (Salomon 1987). The Enlightenment fostered a close relationship between science and government, with the belief that progress in science would ensure the progress of humanity. This relationship continues today.

> States have become nearly everywhere the main patrons of basic research -- particularly where private benefits are low and public benefits are high. States, further, have exercised considerable control over detailed public allocations for science; defined topical research boundaries; steered private investment in science, to some extent or another; and regulated degrees of scientific interdependence with the outside world. States have relied on science and technology to secure their political, economic, and strategic viability (Solingen 1994).

In Europe, the science-government alliance was established well before the twentieth century, but in the United States laissez-faire, extending the theme of the free market, was an article of faith. Even in the latter half of the twentieth century, science-government institutions in each location differed in three important ways: (1) U.S. bodies such as the Department of Energy’s Office of Science and Technology Policy are informational and advisory only, while European institutions responsible for science policy have funds for launching research programs; (2) the members of advisory committees in Europe are much more likely to include social scientists than are committees in the United States, reflecting a broader view of what constitutes science in Europe; and (3) the U.S. agenda focuses on national security problems and military research, while the European agenda focuses on civilian interests such as education, basic research, and industrial matters.

Since World War II, science policy and the principal justifications for public sponsorship of science in the United States have reflected a utilitarian definition of science, as articulated by Vannevar Bush (1945) in his enormously influential report, *Science, the Endless Frontier.* The first justification has been that science is important to national defense: excellent science before and during the war directly led to the weapon that won the war, and excellent science will keep the country in the forefront of military technology. The second justification has been that science plays a critical role in national economic growth and competitiveness: basic scientific research provides the fuel for U.S. industry to continue to grow and dominate world markets through innovation.

The original view of science as an intrinsically valuable activity and of scientists as independent intellectuals did not disappear. Vannevar Bush affirmed the need for scientific independence by writing, “Support of basic research in the public and private colleges, universities, and research institutes must leave the internal control of policy, personnel, and the method and scope of the research to the institutions themselves. This is of the utmost importance.”

The formulation of science that has dominated U.S. policy since World War II has been increasingly challenged by changes in the nature of science, post-Cold War globalization, the patterns of funding for research and development, and the conceptualizations of science and society held by both academics and the public.

The growth rate of support for research and development (R&D) in the United States (public and private) increased in the mid- to late 1990s, in contrast to earlier years in the decade, when increases in R&D spending did not keep pace with inflation (National Science Board 1998, 2000). However, federal R&D funding (as a percentage of all R&D funding) has fallen almost continuously in real terms for decades. From a high of 75 percent of all R&D funding in the United States in 1963, the federal share fell to 59 percent in 1998 (Figure 1). Funding by industry accounted for all growth in each of the three R&D categories: basic research, applied research, and development. The non-manufacturing sector led the way, driven principally by increases in funding for R&D in information technology and biotechnology.

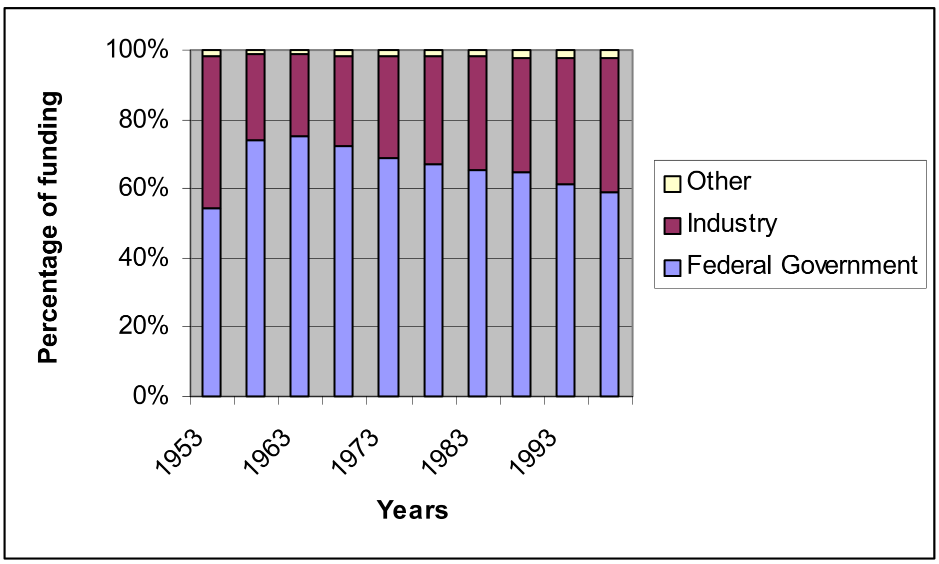

Figure 1. National R&D Expenditures, by Source of Funds, based on constant 1992 dollars (From National Science Board 2000).

Over this same period, the distinctions between the three categories of R&D have blurred – and indeed the distinction between research and development has faded as well. Traditionally this categorization has been based on whether the results of a particular kind of research are appropriable by individual firms. Basic research, driven by a need to understand fundamental processes, is generally classified as a “public good,” that is, its results cannot be patented or otherwise used for private gain. Therefore, it has been considered appropriate for the federal government to sponsor such research. Applied research and development, from which firms can reap the competitive benefits of new products and processes, has traditionally been considered the appropriate province of industry.

But where is the line between "basic" and "applied"? The chemical industry defines its needs in basic science terms such as new catalysts.[2] New life forms discovered in the "white smokers" of the ocean floor are immediately seen to hold the promise of producing tailor-made proteins to clean toxic contaminants from the environment. Gene sequences may be patentable. Harvesting methane hydrates from the ocean floor to produce clean energy requires fundamental physical and chemical research. "Is research on a new computer software algorithm basic or applied? Is research seeking the genetic origins of a particular disease basic or applied? Much economically important research now falls into this hazy area in which research is risky and seeks some new, fundamental understanding -- characteristics of 'basic' research -- but has relatively obvious and marketable applications" (Council on Competitiveness 1996).

In such an environment, science policymakers have been engaged in answering new questions. Does it make any sense to try to separate "public good" activities from profit-making efforts? On what basis can federal funding of scientific research be justified? Should all R&D be conducted by private firms, following current trends? Rosenberg (1990) lists several reasons why private firms conduct basic research: return on investment (at least enough to cover the investment), the advantages of being the first with a product or service, long-term market positioning, to solve practical problems, to direct applied research in profitable directions, to monitor and evaluate research being done elsewhere, and to qualify for government contracts. Perhaps these motivations will be sufficient to conduct the basic research needed.

However, these are not the only definitions of science and justifications for public support of research – or bases for opposition to such public support – that have been part of the public dialogue during the post-war period. Alternatively, science has been attacked by some as the Leviathan, the modern juggernaut, devoid of ethics and separated from public values, that has given humankind pollution, modern warfare, Nazism, and so forth, and hence as deserving of public sanction rather than support.

These alternative viewpoints have been gaining momentum. There are indications that the dominant view of the relationship between science and society outlined by Vannevar Bush shortly after the end of World War II has been breaking down. As Stokes (1997:105) says:

> The stylized scientist who might be imagined from Bush's canons of basic research – an investigator remote from ideas of use who curiosity leads to discoveries that only later provide the basis of new technology – offers a progressively less adequate image for modern science.

Alternative viewpoints have led to reinvigorated discussions about science as an intellectual and ethical activity and the need for science, and science policy, to be conducted in dialogue with non-scientific citizens and policymakers.

Conceptual and Operational Definitions of Science and its Social Value

How is value, and hence "excellence," understood regarding science? Theoretical texts about the sociology of science explore alternative conceptualizations of science and its value, as well as alternative standards of excellence for science. These conceptualizations are revealed in the

[2] This and the following examples are taken from DOE 1999, a summary of the basic research funded by the U.S. Department of Energy's Office of Science.

justifications given for the funding of scientific research and for the seeking of such funds. As mentioned above, Bush's (1945) report to the President invoked at least two conceptualizations of science and its value: (a) heroic activity and (b) the engine of military security and of progress. An examination of the following differing conceptualizations of what science is, the justifications for funding science, and the bases for evaluating science as excellent (or less than excellent) provides insight into science policy and public support issues that are affecting both science funding and science implementing organizations.

Science as a Quest for Discovery

Science is often thought of as uncovering (or discovering) the general laws of the universe, the ultimate Truths about how the Earth was made and continues to function, how plants and animals live and interact, and how humans came to have a place in Earth. The fact that so many "ultimate truths" and "general laws" have been "discovered" and then discarded is, first, evidence that science has not yet discovered the Truth and laws (which, nevertheless, exist) and, second, that science is making progress toward this goal (i.e., each candidate truth or law is a successive approximation). Many physicists and those who think of physicists when they think of scientists hold this view. In exploring the quantum world and what happened during the first few seconds of the Big Bang, scientists think of themselves as unlocking the secrets of how the universe works. Those who hold this view think of science like religion (Fuller 1997), a highly moral quest with devoted practitioners (hierophantic or heroic scientists) who are held in some awe by nonscientists who lack the requisite training and knowledge.

In this view, if scientists do "discover" how the universe works, then they are engaged in excellent science. Since, of course, the lay persons outside science cannot judge what is a valid general law of the universe and what is not, they can either unquestioningly accept what scientists tell them (and many do) or try to judge how convincing scientific claims to truth are.[3] The justification for providing public funding for science is a kind of faith in the heroic quest, a confidence that scientists will make discoveries as they have in the past.

Science as the Driver of Technology and Economic Prosperity

Another common view is that science has made technological progress possible.[4] For example, in this view the principles of Newtonian mechanics lie behind all the technological marvels of the Industrial Revolution. Certainly in the twentieth century, science and technology have been linked. The clear example is the tight link between advances in nuclear science, atomic weapons, and nuclear generation of electric power. Bush (and many others after him) conceived of "basic" science as a vast reservoir upon which creators of technology can draw for ideas and knowledge. Today the initialism S&T (for science and technology) is common in policy papers and journal articles; the two are thought of as a continuum. Michael Porter (1991) believes that part of government's role in stimulating innovation is to invest in basic research as well as in educational systems and infrastructure, although he clearly states that such investment must be consciously advanced and specialized.

---

[3] Scientists themselves typically understand advances in understanding to be important only retrospectively, by validating published findings and working out the implications of a "discovery."

[4] Never mind that many inventors have only a hazy idea of the science involved in their technologies.

Most researchers agree that a principal element in economic dominance ("competitiveness") is a steady stream of innovation, but the connection between technological innovation and basic research is not a simple one-way arrow.[5] In many cases, first the technology works, then scientific research is undertaken to find out why -- or why it fails over time. Carot, for instance, created a theory of thermodynamics while trying to improve the efficiency of Watt's steam engine, and Joule formulated the law of the conservation of energy while investigating alternative sources of power generation at his father's brewery. Technology, then, has been a source of empirical knowledge that provides a stimulus to scientific research, which in turn may make major breakthroughs that allow technology to advance or be transformed (Rosenberg 1982).

In this view, excellent science comprises the theories and knowledge that are the basis for useful and profitable technologies. Basic research on advanced materials, for example, has led to progress in computer technology, high performance engines, lightweight but strong automobiles, and plastics for thousands of uses.

Science as Monster

In opposition to the previous definitions, a view of science as the new Leviathan: "a body of knowledge which is esoteric, inhuman, and increasingly dominant" (Ravetz 1996[1971]:24) has been a persistent counterpoint to these optimistic definitions of science and technology. "The mid-1960s had seen a vociferous critique of the social consequences of unfettered technological development, ranging from the environmental damage caused by the side effects of modern science-based production processes to the use of sophisticated electronics in the war in Vietnam" (Dickson 1988[1984]:30). There was a backlash against even the peacetime uses of science, which was equated to its destructive products: DDT, Agent Orange, nuclear weapons and radioactive materials, and other deleterious and deadly things spawned by scientists who are characterized as black magicians. This view is represented today by the *Living Simply* movement and by many environmentalists, who see many of the products of science as inhuman, destructive, and unnecessary. Current debates include those concerning genetically modified organisms (GMOs), the use of human stem cells, and cloning.

A less absolutist variant of this definition characterizes science as neither good nor evil in itself, but needing to be under the control of moral persons and open to scrutiny by citizens or their accountable representatives. A recent edited book (Soden 1996) takes this view. Science, Soden says, is not necessarily good for us. Medical cures may seem wonderful, but treatments themselves can cause severe problems, including the prolongation of life. Products may be at the same time convenient and the cause of toxic wastes. Moreover, scientific inputs into policy often clash with government's attempts to manage scientific activities, with the result that scientific endeavors are fragmented; resulting policy is also fragmented or unclear. In such a situation, policy fails to guide science with, perhaps, the "unforeseen and incalculable consequences of technical failure" (Soden 1996:2). In both these views, science must be environmentally and socially responsible as well as reflexive and self-limiting. To be excellent, science would have a moral dimension.

[5] For an overview of approaches to quantifying the contribution of basic research to economic growth, see Smith and Barfield (1996).

Science as Constructed Knowledge

Another conceptualization of science revolves around the actual practice of science, from the craftwork of scientists in laboratories to the scientific communities in which scientists debate and form a consensus about what should be recognized as scientific knowledge and theory. Ravetz (1996[1971]) explores this concept, which looks at how science is actually done. Two elements are necessary for scientific craftwork, says Ravetz: (1) a community of scholars with common standards and commitment and (2) individuals with high personal integrity. The process of developing truth in a scientific inquiry depends in the highest degree on specialized training and knowledge, with judgment a critical component. The objects of inquiry are intellectual constructs (not natural things), studied as problems for which the questions may change during the course of the investigation – or even prove to be unanswerable. Furthermore, scientific methods are mostly informal and tacit, and the craft knowledge of the scientist must guide the selection and transformation of the research result through the publication process. The usefulness of published results for research by other scientists will determine whether or not they are judged sufficiently confirmed and significant to become part of the body of facts and theories in a discipline. Essays in Pickering (1992) provide concrete and elaborate examples of science as craftwork.

The standards of the craft (e.g., how an experiment is set up or a research study is designed), how well scientist-researchers adhere to them, the ethical conduct of scientists in collaboration and peer review, and the judgment of peers all determine the excellence of the science. In this sense, excellence is a name for science that other scientists judge to be highly original and significant to advancing research within that scientific community. This reflects an emphasis on the methods of knowledge creation (laboratory work, instrumentation, peer review, usefulness by other scientists) rather than a focus on the ends of science (discoveries and technology), although the judgment is still significantly based on the "significance" of the discovery or development (theory, method, empirical evidence).

Science as Discourse

A recent trend, represented by Brown (1992, 1998) and Gross (1990), looks at how science and scientific knowledge are made through discourse, using literary devices like narrative, metaphor, and irony. Against the positivist view that scientists add to a stock of verifiable knowledge through objective observation and repeatable experiments, this view holds that science relies on rhetoric to shape reality and that scientific propositions and knowledge are always open-ended and contestable (Brown 1992). The narrative stories and tropes that scientists tell one another build both knowledge and community. Scientific communities, like other communities "are co-constituted through communication transactions in which participants coauthor a story that has coherence and fidelity for the life that one would lead" (Fisher 1992).

The construction and maintenance of science as a social category depends upon scientists' abilities to convince public and policymakers that science is a unique endeavor that is somehow useful to them. Excellent science might then be noted by metaphorical explanations that are most persuasive to scientists within scientific communities and their patrons in funding organizations and the public. Case studies in Gross (1990) include Darwin's journals as a study of developing scientific narrative, and private and published papers that document the race to explain DNA.

Justifications for Public Funding of Science since World War II

Especially for its champions, science is often presented unproblematically in terms of one conceptualization or another – or as two or more at once. In U.S. politics, the idea of science as the engine of technological dominance – military and industrial – has been invoked again and again to justify both no-strings funding for scientific research and the need to provide scientific advice to the President and Congress. The conceptualization of science as the fount of technological progress has often been joined to that of science as the search for disinterested truth. *Science, the Endless Frontier* links these two concepts. The first is evident in the statement that "without scientific progress no amount of achievement in other directions can insure [sic] our health, prosperity, and security as a nation in the modern world" (Bush 1945:5). Vannevar Bush cites the products of science: radar, penicillin, full employment from new products and industries (radio, air conditioning, rayon, plastics), and agricultural advances. Far from controlling or planning science, Bush recommends that scientists be enlisted to advise the government and that laws and regulations be revised to encourage industry to increase R&D activities.

In making these joint claims for science, Bush was echoing the German scientist, Hermann von Helmholtz. In the nineteenth century Helmholtz asserted that the disinterested search for truth would lead to economic and industrial progress, thus providing a reason to fund scientific research (Helmholtz, cited in Ravetz 1996[1971]:38-39):

> In fact, men of science form, as it were, an organized army labouring on behalf of the whole nation, and generally under its direction and at its expense, to augment the stock of such knowledge as may serve to promote industrial enterprise, to adorn life, to improve political and social relations, and to further the moral development of individual citizens. After the immediate practical results of their work we forbear to inquire; that we leave to the uninstructed. We are convinced that whatever contributes to the knowledge of the forces of nature or the powers of the human mind is worth cherishing, and may, in its own due time, bear practical fruit, very often where we should least have expected it.

In other words, science should be supported for the sake of increasing the human store of knowledge in the most general way – but the government, by pathways that cannot be foreseen, may expect to reap some very practical benefits also.

The influence of Bush's report to the President has been enormous, not only in defining science as the source from which technology can be drawn, but also in setting up a linear model of how science leads to technology. The linear model starts with the concept of science as the quest for truth. This is "basic" research, which "is performed without thought of practical ends. It results in general knowledge and an understanding of nature and its laws" (Bush 1945:18). Basic science seeks truth, "new knowledge" developed in "the purest realms of science" (Bush 1945:19). The linear model proceeds with government support of basic research, which will strengthen industrial research, which in turn will produce technologies. As Bush tells the story of nuclear weapons development, this seems to be a very compelling model.

Arnulf Grübler (1998:77-78) articulates the model as follows:

> The distinction between basic and applied science and the development of many technologies from scientific results suggests a linear model of technological change. This model is a more detailed stage representation of

the life cycle typology invention, innovation, and diffusion discussed previously. The states of this model are as follows:

- Basic research produces new scientific knowledge (discoveries)
- Applied research leads to proposed applications (patents)
- Further applied research and development refines this knowledge sufficiently to justify substantial investments in new technology (development)
- Investments are made in new production facilities, equipment, and specific products (innovation)
- Experience leads to improvements and adaptation in early applications (early commercialization)
- Widespread commercialization leads to new levels of technical standards, economic performance, and productivity (diffusion).

To these stages we could add three more:

- Experience, learning, and feedbacks from customers lead to further technological and economic improvements and to wider fields of application.
- Pervasive diffusion leads to macroeconomic, social, and environmental impacts.
- Such impacts lead to scientific research and new information on causes of and possible solutions to adverse impacts.

This takes us back to square one, and the whole sequence starts again. Following these steps in the order just presented represents and science or technology "push" view of technological change. Were we to follow essentially the same steps but in reverse order, we would have a "demand pull" view of technological change. Both are extreme perspectives. The first views technology development as driven exclusively by opportunities; the second views it as driven exclusively by needs.

Both linear models have been largely dismissed in the literature in favor of models with multiple feedbacks and various factors driving different phases of a technology's life cycle. In early phases science/technology push factors may dominate, whereas in later phases demand pull factors may be more important.

There is a subtle tension underlying the dual quest-for-truth and engine-of-progress justifications. Scientists should be intellectually free to pursue the research that they judge to be needed (using scientific criteria), while at the same time funders should trust that the scientific results that emerge from scientist-directed research will strengthen the nation's defense capability and economic dominance. The counter position, also underpinned by a conceptualization of science, is that excellent science could improve the health and well-being of mankind, but that scientists cannot be trusted to make the right decisions about the ends (or the means) of their science, and that defense capability and economic growth are not self-evident goods. All of these issues revolve around the relationship of science to government and of both to the rest of American citizens.

However, the issues embedded in a Bush-like justification of federal support for science remain largely unexplored by the scientists and policy writers who attempt to justify government funding for R&D. These include Harvey Brooks, Harvard professor and chief architect of the Congressional Office of Technology Assessment (OTA); Phillip A. Griffiths, director of the Institute for Advanced Study in Princeton, NJ and chairman of the committee commissioned to produce *Science, Technology, and the Federal Government: National Goals for a New Era* (1993); Erich Bloch, director of the National Science Foundation from 1984 to 1990 and now a distinguished fellow at the Council on Competitiveness; and Jack Gibbons, another academic (University of Tennessee), former director of the OTA and former director of the Administration's Office of Science and Technology Policy.

Brooks (1968) departs from Bush in providing four, rather than two, conceptualizations of science; however, all four are faithful to the Bush justifications for public funding. First, science can be thought of as an autonomous, self-regulating enterprise. Second, science is the technical overhead on social goals, i.e., we must invest in basic science in order to reap technological benefits. Third, science is a social overhead investment; like investments in education, the returns on investments in science cannot be seen in any one class of improvements, but rather in overall societal (including technological) progress. Fourth, science may be seen as a consumer good; society may choose to spend some of its resources on science as a product that takes its fancy, perhaps like a statue in front of a public building or another not strictly necessary item, such as the space shuttle and station.

A contemporary adherent of the Bush model is Griffiths (1993), who retains the clear demarcation between basic and applied research, although he does not seem to think that the former unproblematically leads to technology. "But excellence in research does not guarantee profitability. The products of basic research must be developed by entirely different skills [than those necessary for basic research itself], including production, service, and marketing, which have little to do with research and development" (Griffiths 1993:21). In the same spirit, he says that relocating researchers from their ivory towers to places where they can do more useful work would "disrupt one functioning component of the process without helping solve problems elsewhere."

Emerging Critiques and Alternatives

Bloch (1994) asserts that science policy still reflects Bush's linear model, with its dual concept of science as a search for truth and as the source from which technology is drawn, although the model has now been disavowed. Bloch himself espouses a model of interdependent science and technology, with no clear boundaries drawn among research, design, and manufacturing. He argues that U.S. government science policy, with its artificial definitions, is now just getting in the way. Bloch goes on to say that the Clinton administration had the right idea by setting science policy and technology policy as coequals, but there are too many Congressional committees involved to effectively update science policy.

Bloch thus implicitly discards the special status of science as a quest for truth, wholeheartedly embracing a single definition of science as the source of technologies such as those needed for high performance computing, advanced manufacturing, and the "Clean Car" initiative. Indeed, science in his view is so mixed with technology that it is pointless and perhaps impossible to tell them apart. He proposes that the government "consider the full spectrum of science and technology activities as a single system and to begin to develop the policy mechanisms necessary to manage these activities effectively" (Bloch 1994:23). Jack Gibbons (1997) agrees that the Clinton administration's science policy is really a technology policy; the support of basic science reflects the view that basic science is the reservoir from which technology is drawn.

In *Pasteur's Quadrant,* Donald E. Stokes (1997) categorizes science on two dimensions: whether or not the research represents a quest for fundamental understanding, and whether the researchers have in mind the uses to which new knowledge will be put. Quests for fundamental understanding without considerations of use he places in Bohr's quadrant, those with considerations of use he places in Pasteur's quadrant. Research that does not seek fundamental understanding with considerations of use are placed in Edison's quadrant, that conducted without considerations of use (mere workings out of established schema – the example given is the Peterson's guides to flora and fauna) are not assigned any famous name. Stokes focuses, as the title of the book indicates, on research that encompasses both a quest for fundamental understanding *and* considerations of use – like Pasteur's research. The U.S. public, he states, is supportive of science "not for what it *is* but for what it's *for*" (Stokes 1997:98). The public supports science because of its role in ensuring U.S. influence in the world and economic well-being; specific uses include cheap energy, potential cures for cancer, and desalination of water. Although he breaks down the unhelpful dichotomy between basic and applied research, Stokes leaves Bush's contract intact, with the science to be supported redefined to reflect a truer picture of the nature of that science.

Brooks, Griffiths, Bloch, Jack Gibbons, and Stokes agree that the Bush model no longer works well. However, their proposed amendments to the Bush science-society contract simply quibble with the contract terms, leaving intact definitions of science and the justifications for federal support of science. Although they recognize that the distinctions among basic science, applied science, and technology – and between research and development – are impossible to maintain, they nevertheless resurrect the distinctions without the labels (or, in Stokes' case simply reconfigure the distinctions). The strongest justifications for public funding of research remain those that assert a direct relationship between "basic" or public good science and U.S. dominance of war and markets.

What other conceptualizations and justifications are possible? Stokes briefly alludes to the public's fascination with National Geographic stories and visualizations from the Hubble telescope as evidence of "the belief that a civilized people will seek knowledge for its own sake" (Stokes 1997:99). This belief can be augmented by trust in eventual progress and the willingness to provide a hedge against an uncertain future. An investment in "knowledge for its own sake," however, is probably a weak justification as far as Congress is concerned; science would be unable to compete for federal dollars with military preparedness, Social Security and Medicare, and even other social welfare programs.[6] Moreover, the phrase "knowledge for its own sake," although it sounds pure and high-minded, carries with it some assumptions that have been strongly challenged by social theorists. These assumptions include the notion that knowledge is "out there" somewhere separate from the knower, that scientists can be totally disinterested seekers after knowledge, and that the pursuit of knowledge is necessarily an elite activity.

[6] Scientific research using this justification would likely be funded more along the lines of the National Endowment for the Arts (NEA), at a small fraction of the present level of funding for research. The present "mission" statement for the NEA speaks of it as "an investment in America's living cultural heritage, serves the public good by *nurturing* the expression of human creativity, *supporting* the cultivation of community spirit, and *fostering* the recognition and appreciation of the excellence and diversity of our nation's artistic accomplishments."

However, the reality is that scientists, like other people, do things for their own purposes: professional development, status, and competition, as well as the excitement of discovery.

In contrast, sociological theories of science demonstrate that the practice and knowledge of science are inherently social and rhetorical. Just as Gödel showed that no ultimate mathematical proof exists, Lyotard showed that science cannot be justified using its own language games; for that we need narrative language. Ravetz (1996[1971]) details the largely tacit and informal social processes by which scientists formulate hypotheses and theories, design methods and specialized instrumentation, and maintain a rich social matrix of mentoring and evaluating other scientists and their work. Gross (1990) and Latour (1987) describe the rhetorical processes by which scientists construct both their work and the resultant bodies of knowledge.

Michael Gibbons (1999) discards both the dominant conceptualizations of science and proposes rewriting the social contract between science and society. In effect, he is advocating a shift from the Bush model of science, with its joined science-as-quest-for-truth and science-as-source-of-technology conceptualizations, to a more democratic science on the order of Brown (1998). The older contract, Gibbons says, went like this:

- Universities provided research and teaching of scientists; in return, they received public funding and institutional autonomy.
- Industry developed applications of science in its laboratories so that the United States would remain dominant; in return, the government filled the gaps between university and industry research in such areas as defense, energy, public health, and standards.

Today the boundaries and roles of these institutions are becoming unclear. Government is becoming more like industry with the shift from defense to competitiveness and quality of life issues and with privatization of public utilities. Universities, too, are becoming more industrial, performing objective-driven research and becoming more accountable for its "products" (see also Press and Washburn 2000). These changes in the parties to the old social contract signal the need to radically revise the old contract.

So there is a shift from valorizing "reliable" knowledge to valuing "socially robust" knowledge. Society is now speaking back to science, transforming it by demanding that the boundaries of review, formerly limited to disciplinary peers be extended to other stakeholders. Gibbons calls this process "contextualization." Scientific knowledge must be validated by both scientific and lay experts. For example, various groups, including ordinary consumers, are demanding voices in the debates about genetically modified organisms. As a consequence, the sites of problem formulation and negotiation have moved from funding and research institutions to the "agora," the public space where science and scientists interact with government and industry funders, consumers, interest groups, and the media. This is where contextualization occurs, outside the laboratory. As established links among expertise, government, industry, and citizens fragment in the agora, the parties to the new contract must seek to construct "collective narratives of expertise.... Experts must respond to issues and questions that are never merely scientific and technical, and must address audiences that never consist only of other experts" (Gibbons 1999:C83). In short, the new contract between science and society "will be based upon the joint production of knowledge by society and science" (Gibbons 1999:C84). Such a social contract would resolve the persistent question about the role of science in policymaking: whether scientists can be disinterested providers of knowledge or whether they are or can be advocates for one position or another (see, e.g., Lamb et al. 1996).

Issues in Science Management

Federal agencies and research organizations funded by those agencies must annually justify their budgets. Changes in the justifications for science that have credence with and support from policymakers and the public will therefore have an impact on these justifications. Currently, the budgetary and programmatic justifications for federal support of basic science are based on one or more of the conceptualizations and justifications discussed in this overview, some of which are under attack. The effectiveness of traditional justifications is likely to be affected by the increasing public debate about science and science policy. In order to rationalize and defend federal sponsorship of basic science, it is important to understand the historical and theoretical foundations for this federal role and how those might be changing.

Changes in societal expectations about the public's role in science and science policy are also likely to affect how and how much federal support is forthcoming. In recent years, various agencies have had to grapple with changing definitions of the public's role in program planning, budget allocation, and decision-making, and how to involve its stakeholders in various aspects of scientific research -- nuclear waste cleanup, for example. Stakeholder involvement has also become increasingly important with respect to medical issues (cf. work in nuclear medicine; genetic analysis) and in the investigation of ways to manage natural cycles (e.g., climate, carbon). The concepts of democratic science and socially robust science can assist science managers in clarifying their own roles and in involving stakeholders in the ethical issues of conducting basic science.

References

Bloch, E. 1994. Updated Science Policymaking: Finishing the Job. *Issues in Science and Technology* Fall:22-26.

Brooks, H. 1968. *The Government of Science*. Cambridge, MA: MIT Press.

Brown, R.H. 1998. *Toward a Democratic Science: Scientific Narration and Civic Communication in a Democratic Society*. New Haven, CT: Yale University Press.

Brown, R.H. (ed.). 1992. *Writing The Social Text: Poetics and Politics in Social Science Discourse.* New York: Walter de Gruyter.

Bush, V. 1945. *Science, the Endless Frontier: A Report to the President on a Program for Postwar Scientific Research*. Washington, DC: Reprinted 1960. National Science Foundation.

Council on Competitiveness. 1996. *Endless Frontier, Limited Resources: U.S. R&D Policy for Competitiveness*. Washington, DC: Council on Competitiveness. Also available at http://nii.nist.gov/coc.html

Dickson, D. 1988 [1984]. *The New Politics of Science*. Chicago: University of Chicago Press.

U.S. Department of Energy (DOE). 1999. *Science Portfolio of the Office Of Science*. Washington, DC: DOE.

Fisher, W.R. 1992. Narration, Reason, and Community. In *Writing the Social Text: Poetics and Politics in Social Science Discourse*. R.H. Brown (ed.). New York: Walter de Gruyter.

Fuller, S. 1997. *Science*. Minneapolis: University of Minnesota Press.

Gibbons, J. 1997. *This Gifted Age: Science and Technology at the Millennium*. Woodbury, NY: American Institute of Physics.

Gibbons, M. 1999. Science's New Social Contract with Society. *Nature* 402:C81-C84.

Griffiths, P.A. 1993. Performance Goals for Science: A Proposal. *Issues in Science and Technology* Fall:21-24.

Gross, A.G. 1990. *The Rhetoric of Science*. New Haven, CT: Yale University Press.

Grübler, A. 1998. *Technology and Global Change*. Cambridge: Cambridge University Press.

Lamb, B.E., N. Burkardt, and J.G. Taylor. 1996. Quants and Wonks in Environmental Disputes: Are Scientists Experts or Advocates? In *At The Nexus: Science Policy*. D.L. Soden (ed.). Commack, NY: Nova Science Publishers.

Latour, B. 1987. *Science in Action: How to Follow Scientists and Engineers through Society.* Cambridge, MA: Harvard University Press.

National Science Board. 2000. *Science Engineering Indicators – 2000*. NSB 00-1. Arlington, VA: National Science Board.

Pickering, A. (ed.). 1992. *Science as Practice and Culture*. Chicago: University of Chicago Press.

Porter, Michael E. 1991. The Competitive Advantage of Nations. In *Strategy: Seeking and Securing Competitive Advantage*. Cynthia A. Montgomery and Michael E. Porter (eds). Boston: Harvard Business School Press.

Press, E., and J. Washburn. 2000. The Kept University. *Atlantic Monthly* March:39-54.

Ravetz, J.R. 1996 [1971]. *Scientific Knowledge and its Social Problems*. New Brunswick, NJ: Transaction.

Rosenberg, Nathan. 1990. Why Do Firms Do Basic Research? *Research Policy* 19:165-174.

Rosenberg, Nathan. 1982. *Inside the Black Box: Technology and Economics*. Cambridge: Cambridge University Press.

Salomon, Jean-Jacques 1987. Science and Government: A European Perspective. In *Science for Public Policy*. Harvey Brooks and Chester L. Cooper (eds). Oxford: Pergamon Press.

Smith, Bruce LR., and Claude E. Barfield. 1996. Contributions of Research and Technical Advance to the Economy. In *Technology, R&D, and the Economy*. Bruce L.R. Smith and Claude E. Barfield (eds). Washington, DC: The Brookings Institution and American Enterprise Institute.

Soden, D.L. (ed.). 1996. *At The Nexus: Science Policy*. Commack, NY: Nova Science Publishers.

Solingen, Etel. 1994. Domestic Structures and the International Context: Toward Models of State-Scientists Interaction. In *Scientists and the State*. Etel Solingen (ed). Ann Arbor: University of Michigan Press.

Stokes, D.E. 1997. *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington, DC: Brookings Institute Press.